

Description

Open-Path/Free-Space Optical Communication System and Method Using Reflected or Backscattered Light

BACKGROUND OF INVENTION

[0001] RELATED APPLICATIONS

[0002] The present application is a U.S. National Stage application claiming the benefit of prior filed International Application, Serial Number PCT/US02/02866, filed January 30, 2002, which International Application claims a priority date of January 30, 2001 based on prior filed U.S. Provisional Application Serial Number 60/265,022.

[0003] *BACKGROUND OF THE INVENTION*

[0004] Field of the Invention

[0005] This invention relates to systems and methods for relaying information between two or more points by using laser or optically generated conductive transport means through the atmosphere to convey the information.

[0006] Description of the Prior Art

[0007] Open-Path, or Free-Space Optics is a line-of-sight technology that enables optical transmission of data, voice and video communications through the

, providing optical connectivity without the need for expensive fiber-optic cable. Propagating optical signals through the air requires light signals generated by the use of either light emitting diodes (LEDs) or lasers.

[0008] Free-Space optical systems can operate over a distance of several kilometers, provided the transmitting laser and the receiver are in a direct line-of-sight relationship. When a clear line of sight between the source and destination does not exist, optical communication between the devices has not been feasible because physical objects positioned in the line-of-sight path easily block direct line-of-sight communication. Thus, a cubical wall may separate two computers in a room from one another, for example, and prevent optical communication therebetween.

[0009] However, at the time of the present invention, it was not obvious to those of ordinary skill in the art how this fundamental problem could be overcome.

SUMMARY OF INVENTION

[0010] The long-standing but heretofore unfulfilled need for a communication device that enables data transfer between a data communication device transmitter and a data communication device receiver where a barrier means prevents line-of-sight communication therebetween is now met by a communication device for transmitting signals to a receiver that includes an optical light source adapted to generate light, a detector adapted to detect light, and an optical diffuse reflecting target in line-of-sight relation to the optical light source and in line-of-sight relation to the detector. A modulating device is connected in modulating relation to the optical light source and the detector is adapted to demodulate light reflected or backscattered by the target.

- [0011] The light source is selected from the group consisting of a laser light source and a light-emitting diode.
- [0012] In one embodiment, an enclosure having at least one wall member, or at least one ceiling member, or at least one floor member houses the optical light source, the detector, and the barrier. The at least one wall member, ceiling member, or floor member serves as the target.
- [0013] In another embodiment, the communication device includes a first data communication device adapted to transmit data and a laser source modulated by the first data communication device. A transmitter telescope is adapted to aim modulated light from the laser source to the light-reflecting target. A second data communication device is adapted to receive data and a transducer in the form of an optical detector is adapted to generate electrical signals corresponding to detected optical signals is connected in driving relation to the second data communication device. A receiving telescope is adapted to collect modulated light reflected from the light-reflecting target and to deliver the modulated light to the optical detector. Moreover, an optical bandpass filter is electrically connected between the receiving telescope and the optical detector. A barrier means preventing line-of-sight communications between the first and second data communication devices is adapted to be positioned between the first and second data communication devices. The transmitter telescope causes modulated light to reflect from the light-reflecting target and the receiver telescope causes reflected light to focus on the optical detector. Accordingly, the second data communication device receives electrical signals from the first data communication device.

[0014] The light-reflecting target may be a ceiling, wall, or floor of a structure adapted to house the first and second data communication devices. The light-reflecting target may also be a natural structure such as a tree, or a man-made structure such as a building, external to a structure adapted to house the first and second data communication devices.

[0015] In another embodiment, the device again includes a first data communication device adapted to transmit data and a laser source modulated by the first data communication device. A first optical lens means having a ≥ 2 steradians field of view is positioned in light dispersing relation to the laser source. A second data communication device is adapted to receive data and an optical detector adapted to generate electrical signals corresponding to detected optical signals is connected in driving relation to the second data communication device. A second optical lens means having a ≥ 2 steradians field of view is positioned in light focusing relation to the optical detector. A barrier means preventing line-of-sight communication between the first and second data communication devices is adapted to be positioned in an enclosure between the first and second data communication devices.

[0016] Accordingly, the first optical lens means causes modulated light to reflect or backscatter in a diffuse manner from the ceiling, walls, or floor of the enclosure and the second optical lens means causes reflected light to focus on the optical detector. The second data communication device therefore receives electrical signals from the first data communication device.

[0017] The first optical lens means may take the form of a hemispherical short focus

lens or it may be provided in the form of transmitter optics.

[0018] An electrical signal conditioning means is electrically connected between the first data communication device and the laser source.

[0019] The second optical lens means may take the form of a hemispherical short focus lens.

[0020] An electrical signal conditioning means may also be electrically connected between the optical detector and the second data communication device.

[0021] An optical bandpass filter may be electrically connected between the second optical lens means and the optical detector.

[0022] Another embodiment includes a LIDAR communication system. More particularly, a laser is adapted to generate a LIDAR beam and a transmitting device is provided for modulating the laser. A transmit telescope is adapted to aim the LIDAR beam at a remote target and a receiver telescope is adapted to collect the LIDAR beam after the LIDAR beam has reflected or backscattered from the remote target. An optical detector means adapted to generate electrical signals upon receiving reflected light from the remote target is in light-receiving communication with the receiver telescope. A data-receiving device is adapted to receive electrical signals from the optical detector. In this way, the data-receiving device receives data from the data-transmitting device even when the data-receiving device is positioned in a location distant from the data-transmitting device even when at least one obstacle prevents line-of-sight communication between the data-transmitting device and the data receiving device.

[0023] An electrical signal conditioner adapted to condition signals from the data-transmitting device is preferably disposed in electrical communication between the data transmitting device and the laser. An electrical signal conditioner adapted to condition signals from the optical detector is also disposed in electrical communication between the optical detector and the data-receiving device.

[0024] It is an object of the invention to provide an open-path optical or laser beam communication system that conveys information between two or more points within a building structure even when one or more physical objects are positioned in a line-of-sight path between said points.

[0025] It is a further object of the invention to provide an open-path laser beam communication system that can convey information between two or more buildings even when one or more physical objects are positioned in a line-of-sight path between said buildings.

BRIEF DESCRIPTION OF DRAWINGS

[0026] Fig. 1 is an overall schematic of the laser communication system of the present invention;

[0027] Fig. 2 is a schematic showing the laser communication system inside a closed building;

[0028] Fig. 3 is a schematic of a second embodiment of the invention showing the communication system communicating between buildings; and

[0029] Fig. 4 is a schematic of an expanded version of the Figure 3 system.

DETAILED DESCRIPTION

[0030] Referring now to Fig. 1, it will there be seen that an illustrative embodiment of the novel laser communication system is denoted as a whole by the reference numeral 10.

[0031] System 10 includes laser generator or other light source 12 connected in communication modulation relation to sending device 14, *i.e.* sending device 14 modulates laser generator 12. Transmitter telescope 13 is adapted to aim a laser or other optical beam from laser generator 12 toward a target area 16 which in this embodiment may take the form of an area of a ceiling 18 or similar structure such as a wall, floor, or other suitable light-reflecting surface. The light is scattered from target area 16 and excites sensor 20 attuned to the wavelength or wavelengths emitted by laser generator 12. Sensor 20 is connected in driving relation to receiving device 22. Accordingly, system 10 enables communication of a control function whereby sending device 14 may control receiving device 22.

[0032] Although not illustrated, upon disclosure of the Fig. 1 embodiment, it becomes apparent that receiving device 22 could be similarly connected in driving relation to a second laser generator and sending device 14 could similarly fitted with a second sensor so that device 22 could just as easily control device 14.

[0033] Sensor 20 is attuned to sense scattered light from a remote target area such as target area 16 by means of a highly sensitive device such as a receiver telescope means 24. Accordingly, a straight line-of-sight light path relationship between laser generator 12 and sensor 20 is not required. This

enables operation of a remote device such as receiving device 22 when a straight-line relationship between source 12 and detector 20 is unavailable due to a physical barrier such as obstruction 26 in the straight-line light path.

[0034] Moreover, since the wavelength of a laser source is being detected, there is no need to bounce a wave away from target 16 to regenerate it at an intermediate station. Since the detector or sensor 20 can be a highly sensitive receptor device, there is no need for any amplification of the beam for the device to operate either at the source or at the intermediate target area. This enables use of a fairly low laser source, the sensitivity being a function of sensor 20 and not necessarily laser generator 12 or the presence of an unillustrated amplification device in target area 16 or anywhere else along the extent of the path of travel of the modulated beam.

[0035] In a practical application of this invention, any number of laser generators, sending and receiving devices, sensors, telescopes, and the like may be employed using different target areas or the same target area if the signals are encoded or different wavelengths and optically filtered detectors are used.

[0036] Laser generator 12 may be adapted to emit one of a plurality of wavelengths so that a specific signal will control a selective function at receiving device 22. Moreover, sensor 20 may be encoded to a certain wavelength to perform selective functions at various different locations. In this way, a variety of functions may be controlled at a single site because the sensors are enabled to select a certain wavelength to correspond to a specific response.

[0037] Optical bandpass filter 28 may also be used to pass preselected

s and reject interfering light impinging on detector 20.

[0038] In the embodiment of FIG. 2, denoted 30 as a whole, a hemispherical or short focal length lens 32 scatters light to a plurality of points within a room. Lens 32 may be supplanted by transmitter optics. Data communication device transmitter 34 modulates infrared laser source 35 in much the same way as device 14 modulates laser 12 in the first embodiment. An LED or other suitable light source may also be used. Laser source 35 includes power supply 33. Various electrical components, including signal conditioners 31, provide an interface between transmitter 34 and laser source 35.

[0039] Light from lens 32 impinges upon surface or surfaces 36 and the reflected light is collected by hemispherical or short focal length lens 38. The focused light impinges upon optical bandpass filter 39 which filters out the various wavelengths of light illuminating the room and allows light within the passed bandwidth to impinge upon optical detector 40. Electrical signal conditioner 41 conditions the electrical signal generated by optical detector 40 and said signal is then received by data communication device receiver 42. Communication is thereby established between transmitter 34 and receiver 42 that is not subject to interference by physical barriers or obstacles such as obstacle 43 which may be in the room. Transmitter 34 and receiver 42 may be computers, each of which includes an RS-232 or Internet port for data.

[0040] This application is useful for any size room, including large spaces such as found in warehouse situations.

[0041] Because the light sensed by detector 40 is scattered as a result of impinging on target surface 36, the intensity of the beam emitted by laser source 35 is dictated by the sensitivity of the detector or sensor 40 and not on any requirements of an intermediate or relay system.

[0042] In practice, this system can be used to control functions of televisions, computers, telecommunication devices, Internet devices, printers, and the like. In a specific embodiment of this system, with the use of a # or 2# steradian solid angle lens and detector, any problems caused by obstacle 43 may be overcome with ease. In addition to control functions, both analog and/or digital information may be conveyed in the light beam. This is accomplished by amplitude modulation of the power supply to the light source, such as an electromodulator or a high electromechanical chopper to encrypt the information.

[0043] In the embodiment of Fig. 3, laser communication system 50 is modified to communicate between buildings 52 and 54. In this embodiment, an external target, here shown as tree 51, is used between source 54, modulated by transmitting device 55, and detector apparatus 56 that delivers the data to receiving device 57. Transmitter and receiver telescopes 53 and 59 are used in the same manner as in the embodiment of Fig. 1. Other types of targets may be used, including, but not limited to, clouds, buildings, direct atmospheric aerosols, etc. As in the first two embodiments, the same type of information may be transmitted, and the same sources used, but greater distances are covered. Multiple transmitters may be employed in this system, and optical as well as laser sources may supply the light beam, and there may also be a plurality of receiving devices using different target areas

or the same target area if the signals are encoded or different laser wavelengths and optically filtered detectors are used. Detection system 56 detects the scattered light emanating from target 51, irrespective of any intervening object in the direct optical pathway, which prevents pointcommunication between source 54 and detector 56.

[0044] Fig. 4 depicts an expanded version of this system, denoted 60 as a whole, with an amplitude modulated continuous-wave GaAlAs 1.5 μ m diode laser 62 as the source with encrypted electronic signals being carried by virtue of electronic modulation devices in the system. More specifically, electrical signal conditioners 66 condition signals from data transmitting device 64 and said conditioned signals modulate laser 62. The LIDAR beam generated by laser 62 is directed by transmit telescope 68 through the atmosphere to a distant target 70. The reflected beam is collected by receiver telescope 72 and delivered to optical detector 74. The electrical signals generated by optical detector 74 are conditioned by electrical signal detector 76 and delivered to data receiving device 78.

[0045] It will thus be seen that the objects set forth above, and those made apparent from the foregoing description, are efficiently attained. Since certain changes may be made in the above construction without departing from the scope of the invention, it is intended that all matters contained in the foregoing description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

[0046] It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all

statements of the scope of the invention that, as a matter of language, might be said to fall therebetween.

[0047] Now that the invention has been described,